
# List of Concept Elements

## Over-arching

### Gate-to-Gate:
- CE-0 Data Exchange

## Pre-flight

### Pre-flight Planning:
- CE-1 User optimization for Constraints

## Flight Operations

### Surface Departure:
- CE-2 Intelligent [Taxi] routing

### Terminal Departure:
- CE-3 Free Maneuvering for Separation
- CE-4 Trajectory Negotiation for Separation

### En route: (Separation and local-TFM Conformance)
- CE-5 (a/b) Free Maneuvering
- CE-6 (a/b) Trajectory Negotiation

### En route: (local-TFM)
- CE-7 Collaboration for SUA/Wx/Complexity

### En route / Terminal: (local-TFM)
- CE-8 Collaboration for Arrival Metering

### Terminal Arrival:
- CE-9 Free Maneuvering Around Weather
- CE-10 Trajectory Up link [to avoid] Weather

### Terminal Arrival:
- CE-11 Self Spacing for Accurate Merge
- CE-12 Trajectory Exchange for Accurate Merge

### Terminal Approach:
- CE-13 Closely Spaced Approaches

### Surface Arrival:
- CE-14 Intelligent [Taxi] Routing

**TFM = Traffic Flow Management**


# Research Prioritization for AATT

***Out of 15 Concept Elements, 4 were selected and recommended for research***

**Selection rationale:**

1. **The element focus is long-term, high-risk research TRL 1-4.**
2. **The element focus is largely on DAG-TM.**
3. **The element is essential to a cohesive DAG theme.**
4. **There is a reasonable likelihood of reaching TRL 4 by FY03.**
5. **There is an identified gap in existing government research.**
6. **The element is likely to provide benefits that enable user preferences and/or increase capacity.**

**Technology Readiness Levels (TRL) defined by AATT:**

**TRL 1: Initial Concept Development**
**TRL 2: Proof of Concept Plan**
**TRL 3: Proof of Concept Activities**
**TRL 4: Research Prototype Development**

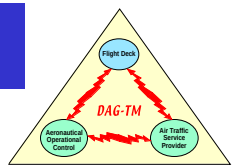

# Detailed Concept Element (CE) Descriptions

## En route:

- (a) Separation assurance & (b) Flow-rate Conformance [Departure, Cruise, and Arrival]
  - CE-5 Free Maneuvering
  - CE-6 Trajectory Negotiation
- Local Traffic Flow Management (TFM) [Departure, Cruise, and Arrival]
  - CE-7 Collaboration for Mitigating Local-TFM Constraints Due to Weather, Special Use Airspace (SUA), and Airspace Complexity (Congestion)

## Terminal:

- Spacing Management (TFM) [Arrival]
  - CE-11 Self Spacing for Merging and In-Trail Separation




# CE-5: En Route Free Maneuvering

Presented by David J. Wing


# En Route (*& Transition*): Free Maneuvering

## for Separation and User-preferred Local-TFM Conformance

**Problem:**

**ATSP cannot accommodate trajectory change requests due to workload; and ATSP-issued clearances often cause excessive deviations for separation assurance or are otherwise not preferred by users**

**Solution:**

- **Air: Equipped aircraft maneuver freely for separation & local-TFM conformance**
  - » **Trajectories account for the latest weather, SUA, and local TFM constraints for airport/airspace capacity (e.g., scheduled time-of-arrival (STA))**
- **Ground: ATSP establishes any necessary flow constraints (e.g., STA), and:**
  - » **Monitors the traffic situation and provides advisories as necessary**
  - » **Assures separation and local-TFM conformance for unequipped aircraft**

**Potential Benefits:**

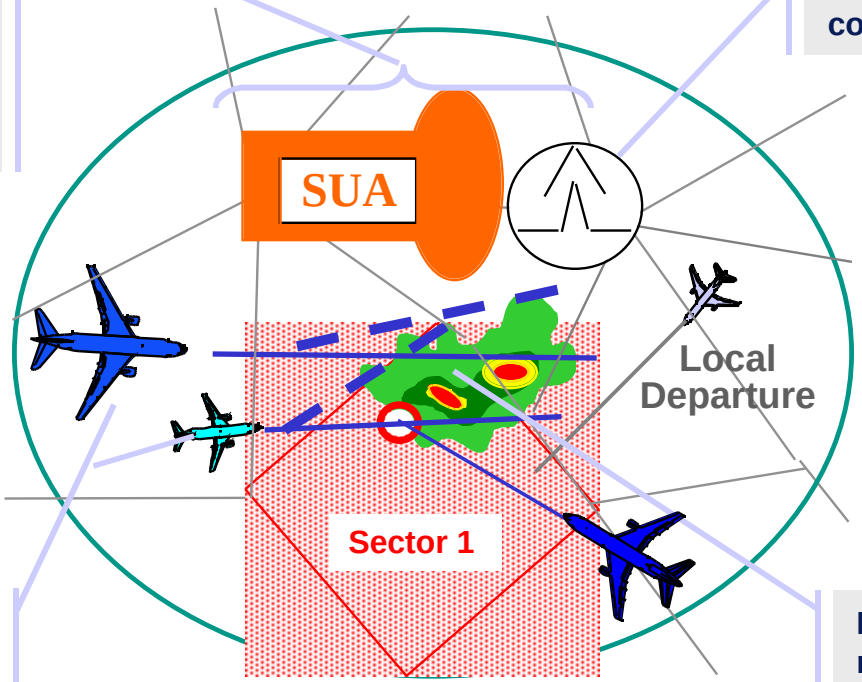
- **Increased safety in separation assurance**
- **Increased user flexibility / efficiency (preferred trajectory)**
- **Increased user flexibility/efficiency in the presence of dynamic constraints**
- **Reduced ATSP workload**
- **Reduced excess separation buffers**
- **Reduced voice communications**


# Technical Challenges of Distributed Air/Ground Traffic Management

- Most CONUS Airspace either constrained or transitional
  - Solution to unconstrained problem not sufficient
  - Separation assurance and 4D local traffic flow management are interdependent
- Universal access requires mixed-equipage operations
  - Preserve participation with current equipage
  - Requires equitable integration with incentives to equip
- Technology development is required to enable concept
  - Compatible air/ground decision-aiding automation
  - Distributed decision-making concept requires human-centered design of technology and procedures
  - Comm, nav, & surveillance infrastructure performance standards are concept-dependent

# Constrained Airspace Challenges

**Plan across multiple sectors and multiple facilities,**
- **involving several human planners**
- **using best available information**



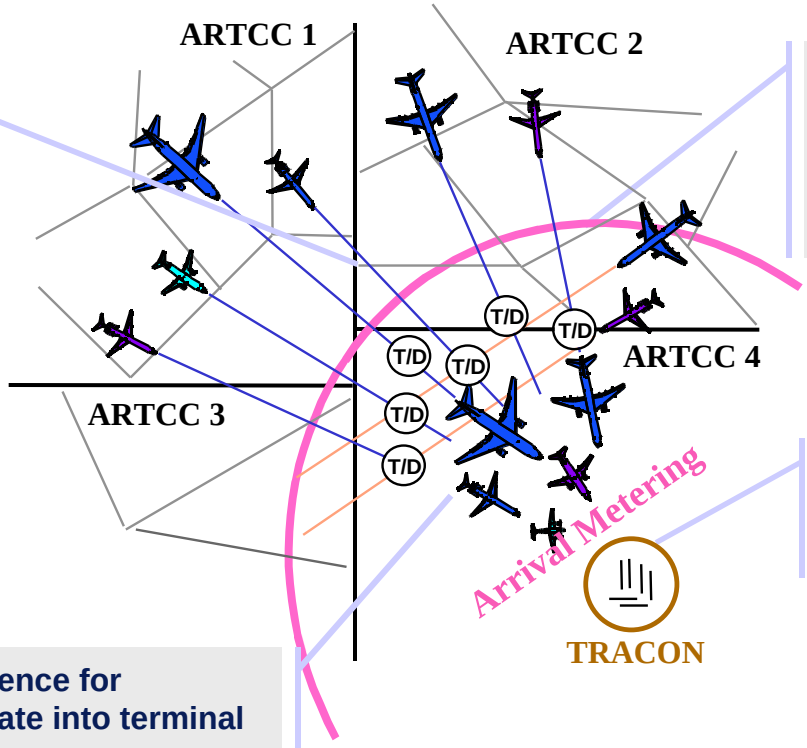

**Maintain passenger comfort**

**Maintain separation with other aircraft, which may have significantly different performance and navigation capability**

**Reroute around weather & restricted airspace while avoiding bottlenecks**

# Transitional Airspace Challenges

Comply with inter-facility flow management constraints (en route spacing)

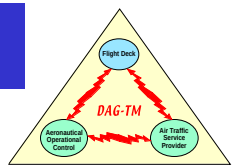



Plan and execute conflict-free user-preferred arrival trajectories.

Comply with terminal flow management constraints (miles-in-trail or metering)

Merge and sequence for maximum flow rate into terminal

T/D Top of Descent

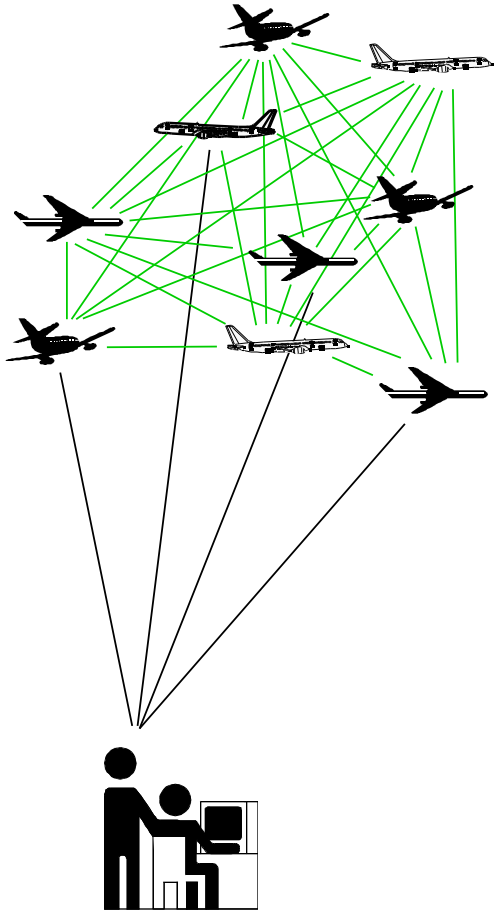



## CE-5 Fundamentals:
# Varied Aircraft Equipage

- "Autonomous" aircraft
  - Voluntarily equipped for flight crew situation awareness & control
    - Airspace / traffic display
    - Hazard prediction and alerting
  - Voluntarily equipped to receive and analyze local data
    - Traffic aircraft, state and intent
    - ATC "constraints" (flow-rate conformance, sequence, airspace, other)
    - Airspace data: NAS status, wx regions
  - Voluntarily equipped to calculate and execute trajectory options that meet -
    - Traffic separation standards
    - Airspace and ATC-issued constraints
    - Performance limitations
    - User preferences & goals
- "Managed" aircraft
  - May or may not have air-ground data link to receive ATC clearances
  - May or may not have airspace / traffic display
  - Must broadcast ownship state data (minimum)

## CE-5 Fundamentals:
# Integrated Operations

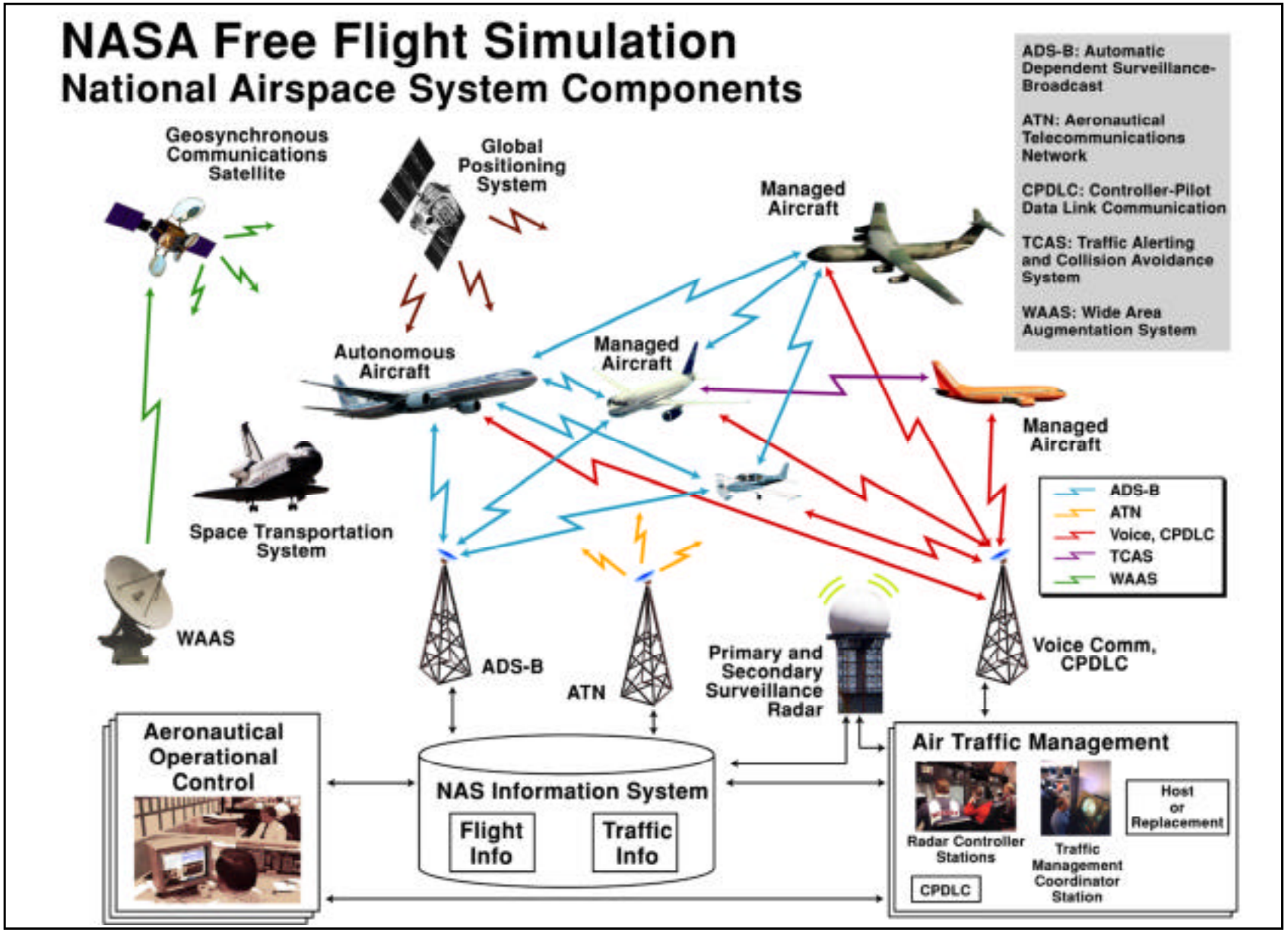
- Airspace contains mix of autonomous and managed aircraft
  - Equal access, no segregation (hypothesis)
  - Traffic management is distributed twice
    - Airborne: distributed among autonomous aircraft
    - Air / ground: distributed by aircraft equipage
- Flight rules for conflict resolution / avoidance, incentive to equip
  - Priority rules: emergency status, maneuverability, equipage level (hypothesis)
  - Maneuver rules



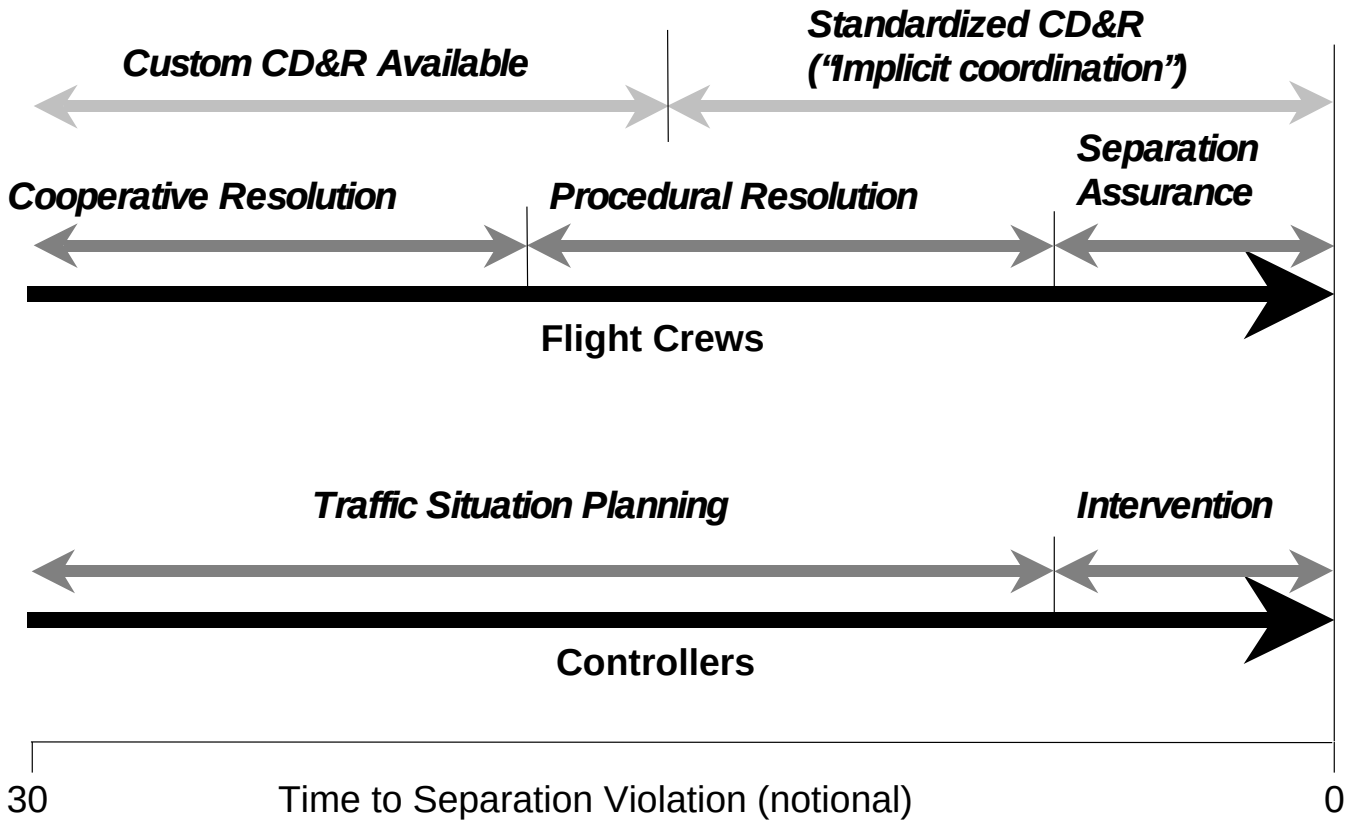

## CE-5 Fundamentals:
# Modified Roles & Responsibilities

- ATC issues “constraints” to autonomous aircraft
  - Flow-rate (required time of arrival at fix)
  - Sequence (aircraft to follow)
  - Airspace (SUA or congested regions)
  - Others (noise abatement, wx impact, speed restriction)
- Autonomous aircraft generates / executes trajectory
  - Ensures traffic separation standards are met
  - Satisfies ATC-issued constraints
  - Conforms to priority / maneuver flight rules
  - Within aircraft performance limitations
  - Optimized for user preferences & goals
- ATC issues trajectory clearances to managed aircraft
  - Ensure separation of managed aircraft from other aircraft
  - Achieve flow management goals for managed aircraft
- Managed aircraft executes “cleared” trajectory

# CE-5 Fundamentals: Information Exchange

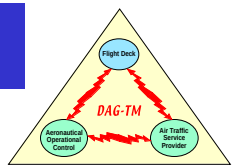


# Resolution Strategy a Function of Time




# Summary of CE-5 Unique Features

- Responsibility for safe and efficient operation of the NAS is distributed between flight crews and ATSP
- Authority for autonomous operations, and responsibility for separation assurance, delegated to aircraft that voluntarily equip with flight deck intelligent decision aids (➞ "autonomous" aircraft)
  - Autonomous aircraft receive constraints from ground-based systems (e.g., required time of arrival at a fix, SUA avoidance) and are allowed to *self-optimize* their flight paths to meet those constraints
- ATSP provides separation and flow management for all other (IFR) aircraft (➞ "managed" aircraft) with the assistance of controller intelligent decision aids
- Autonomous and managed aircraft operations are integrated in airspace




# CE-11: Terminal Arrival Self-Spacing for Merging and In-Trail Separation

Presented by David J. Wing


# Terminal Arrival: Self Spacing for Merging and In-Trail Separation

Problem:

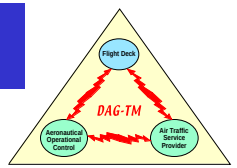
Excessive spacing buffers on final approach reduce arrival throughput and airport capacity

Solution:

- Appropriately equipped aircraft are cleared to maintain separation relative to a leading aircraft:
  - flight deck displays and guidance for:
    - Merging and self-spacing
    - Fine tuning of fixed-time spacing
- ATSP displays & procedures for monitoring

Potential Benefits:

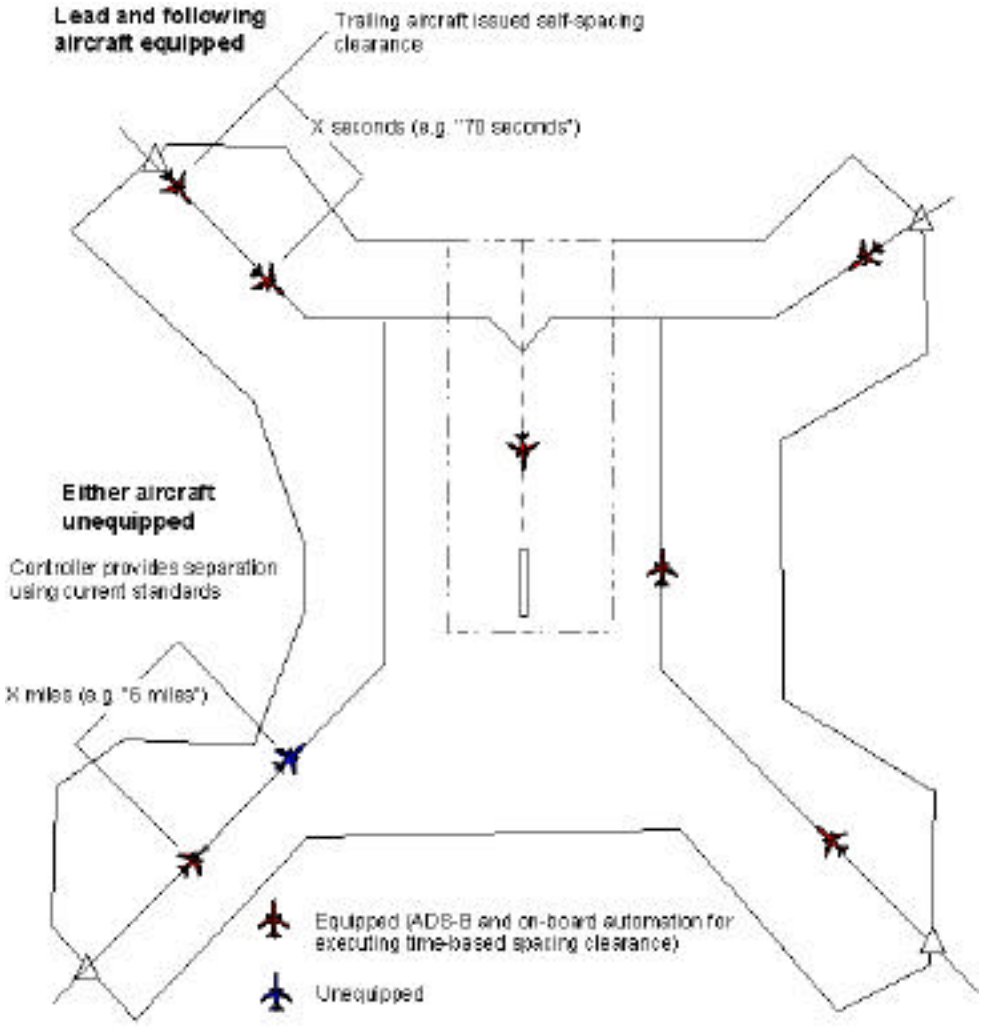
- Increased arrival throughput
- Enhanced ATSP & pilot shared understanding of traffic management plan




# CE-11: Three Phases of Operations

- Phase 1: Spacing
  - Fixed route, in-trail
  - ATM provides spacing interval, manages unequipped aircraft
  - Airborne responsibility for spacing maintenance
- Phase 2: Merging
  - Fixed routes, merging streams
  - ATM provides sequence and spacing, manages unequipped aircraft
  - Airborne responsibility for merging and spacing
- Phase 3: Maneuvering
  - Fixed arrival corridors
  - ATM permits maneuvering within corridors
  - Airborne responsibility for remaining within corridor

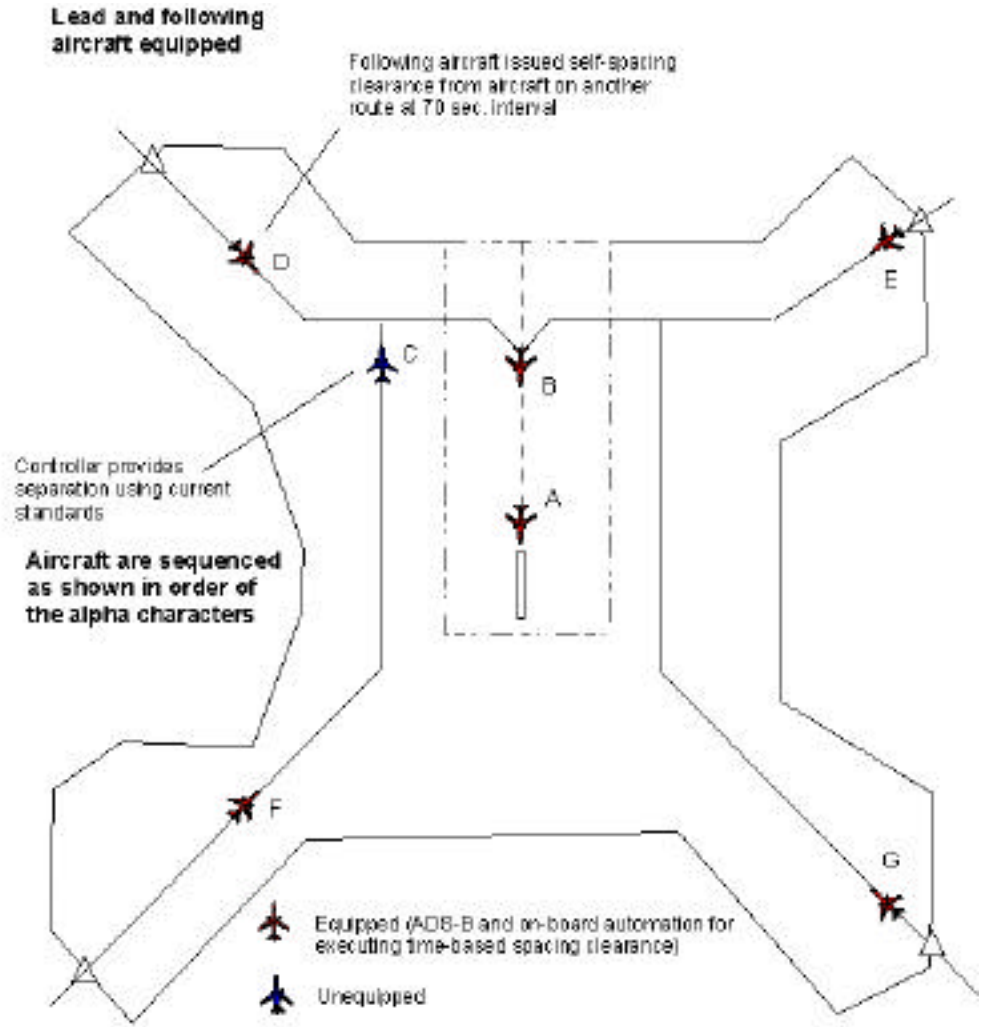
# Phase 1: Spacing




Terminal Arrival Self-Spacing for Merging and In-Trail Separation

**Phase 1**

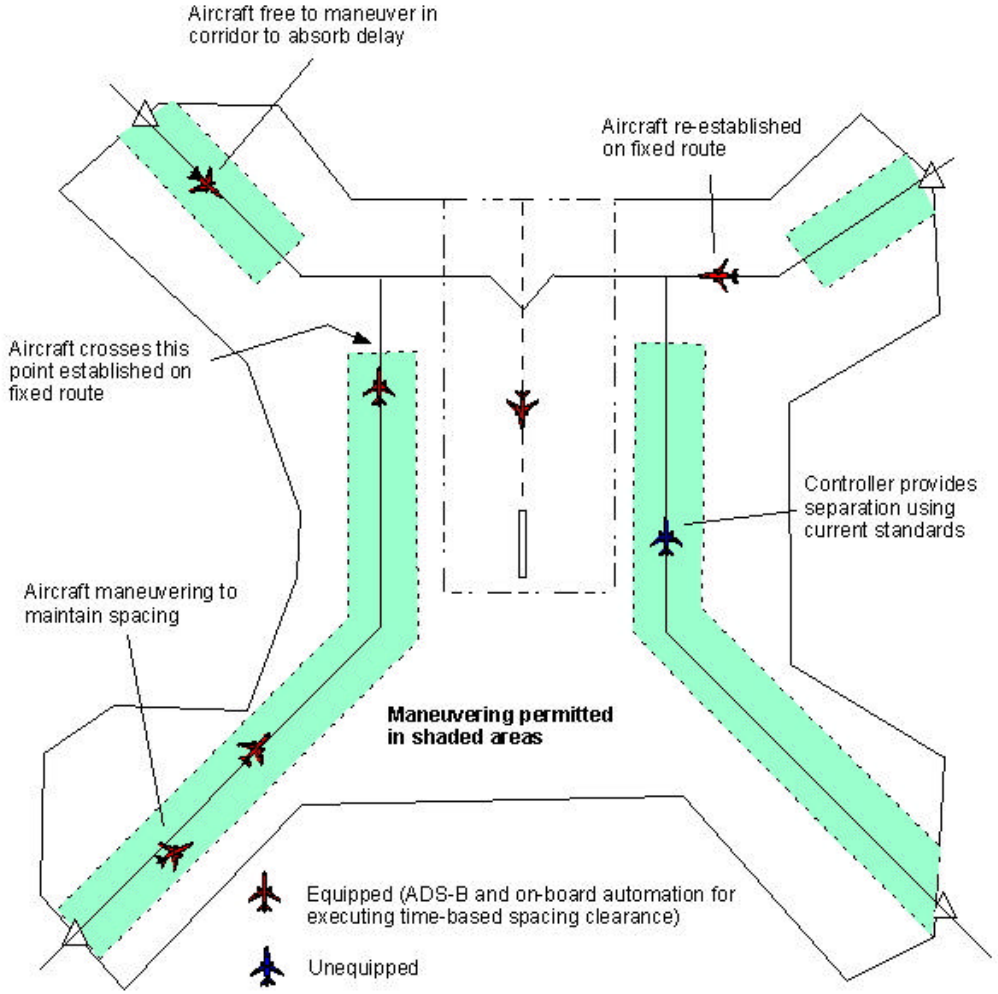
# Phase 2: Merging




Terminal Arrival Self-Spacing for Merging and In-Trail Separation

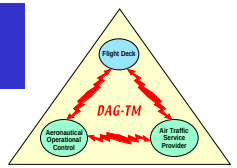
**Phase 2**

# Phase 3: Maneuvering




**Terminal Arrival Self-Spacing for Merging and In-Trail Separation**

**Phase 3**




# CE-11 Characteristics

- Applicable to instrument and visual approaches
- Applicable to mixed equipage operations
- Applicable to segregated performance operations
- Manual or auto-flight implementation
- Mechanism for controlling inter-arrival variability
- Maneuvering flexibility for pilot to meet merging/spacing objectives
- Maneuvering flexibility for aircraft to possibly avoid local convective weather